

REPORT DOCUMENTATION PAGE

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MEMORANDUM FOR PRS (In-House Publication)

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16 Mar 2001

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-VG-2001-053
Miller, T.C., "Crack Growth Rates in a Propellant Under Various Conditions" (VuGraphs)

JANNAF 34th Structures & Mechanical Behavior Subcommittee Meeting (Statement A)
(Cocoa Beach, FL, 26-30 Mar 01) (Deadline: 26 Mar 2001)

CRACK GROWTH RATES IN A PROPELLANT UNDER VARIOUS CONDITIONS

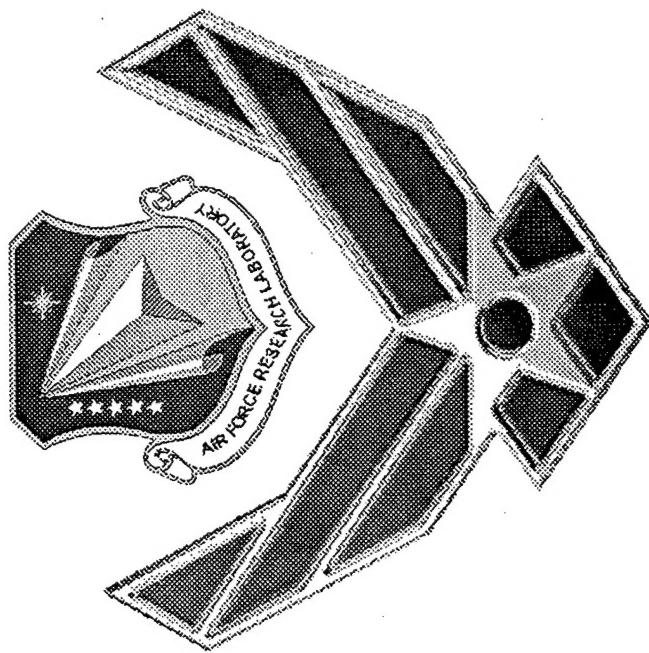
27 Mar 01

Tim Miller

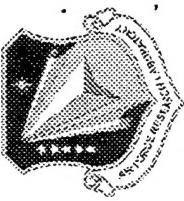
Engineer

Propulsion Directorate

Air Force Research Laboratory



Introduction



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Procedure

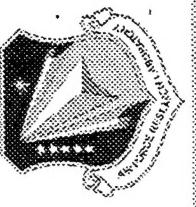
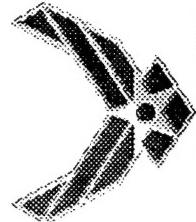
Results and
Discussion

Summary and
Conclusions

- Cracks develop during manufacturing, handling, and storage of rubbery particulate composites
- During the service life, the cracks may begin to grow, but may still be subcritical because the cracks may grow slower than the burn rate of the propellant
- Results for three types of specimens are described. This is done both at ambient and 1000 psi (6895 kPa) pressure.



Complications in Propellant Fracture Analysis



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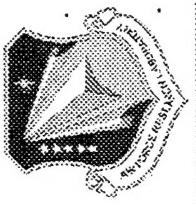
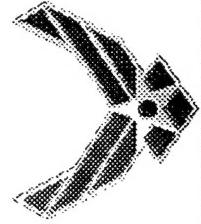
Results and
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Summary and
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- Propellant has unusual properties (time dependence, large deformations, inhomogeneous microstructure) and has not been analyzed as thoroughly as more conventional materials

- Conventional experimental approaches do not always work well because of these properties
- Service conditions vary from long-term low stress conditions caused by thermal loads during storage to short-term high stress conditions caused by pressurization during launch

Experimental Procedure



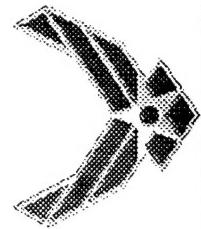
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- Specimen geometries and test matrix
- Test conditions
- Equipment



Specimen Geometries and Test Matrix

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Specimen Type	Figure	Test Conditions
Single edge notched tension	<p>$W = 1 \text{ in (} 25.4 \text{ mm)}$ $a = 0.1, 0.3 \text{ in (} 2.54, 7.62 \text{ mm)}$ $h = 3, 5 \text{ in (} 76.2, 127 \text{ mm)}$ thickness = 0.2, 0.5, 1.0, 1.5 in (5.08, 12.7, 25.4, 38.1 mm)</p>	Strain rate = 0.067 in/in/min, ambient pressure, 1000 psi (6895 kPa)
Biaxial stress	<p>$2W = 8 \text{ in (} 203.2 \text{ mm)}$ $2a = 1.5 \text{ in (} 38.1 \text{ mm)}$ $h = 2 \text{ in (} 50.8 \text{ mm)}$ thickness = 0.2 in (5.08 mm)</p>	Strain rate = 0.100 in/in/min, ambient pressure
Surface cracked	<p>$a = c = 0.4 \text{ in (} 10.16 \text{ mm)}$ $l = W = 2 \text{ in (} 50.8 \text{ mm)}$ height = 2.75 in (69.85 mm)</p>	Strain rate = 0.067 in/in/min, 1000 psi (6895 kPa) pressure

Test Conditions

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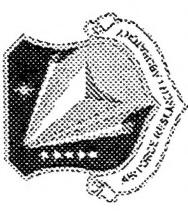
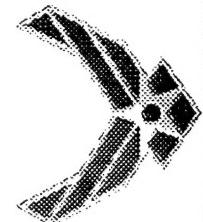
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- Ambient temperature
- Ambient pressure and 6895 kPa pressure (nitrogen gas)
- Constant strain rate tests (0.067 - 0.100 mm/mm/min)

Equipment



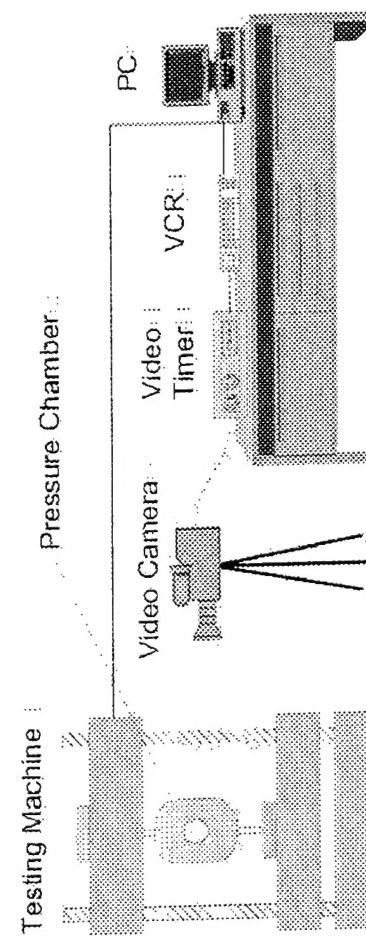
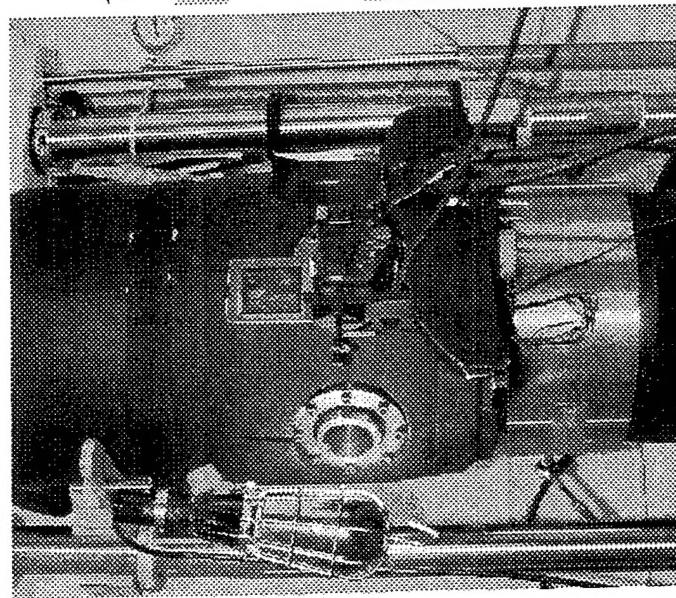
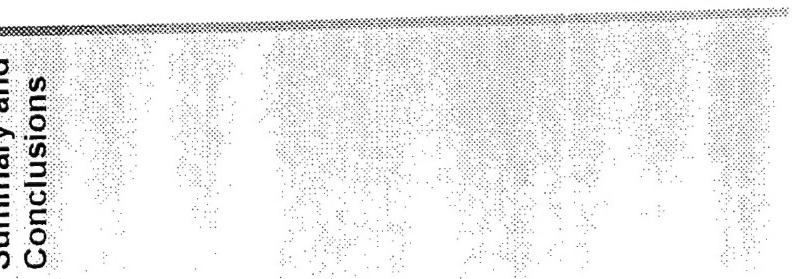
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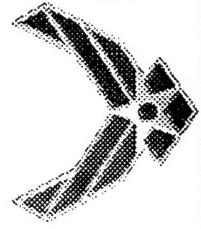
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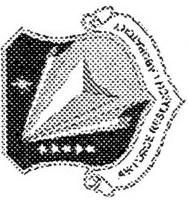
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- Testing machine
- Pressure test chamber
- Videotape equipment





Fixture Is Used to Apply Uniform Displacement Boundary Conditions

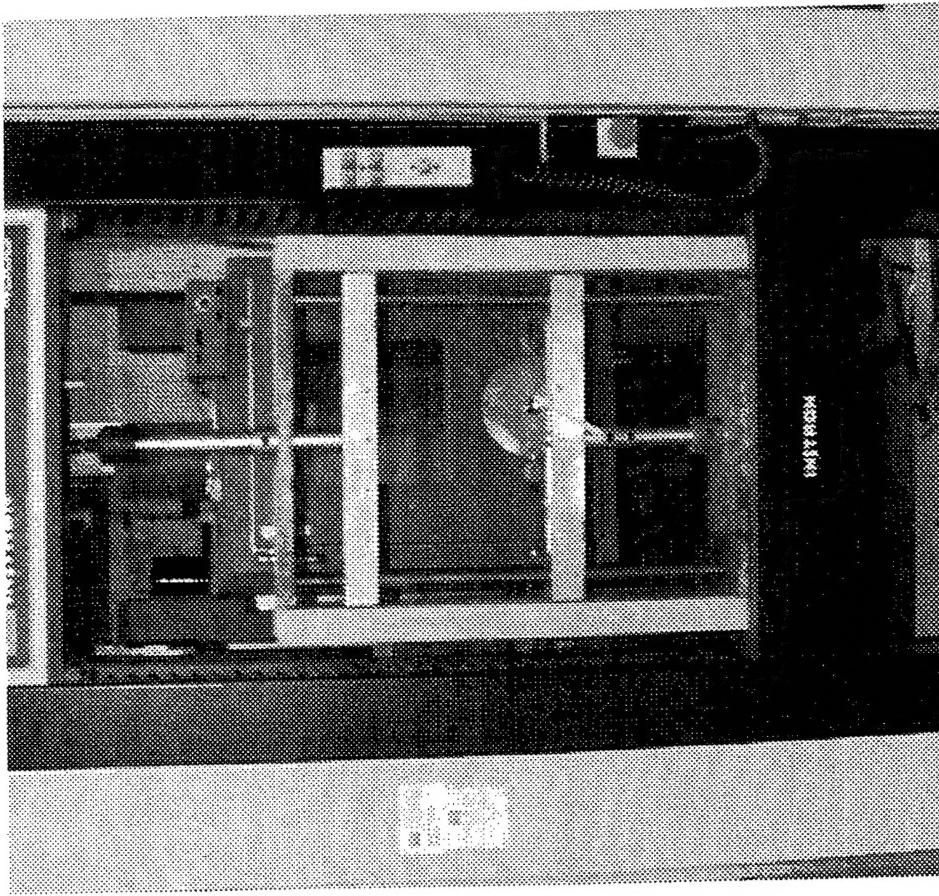


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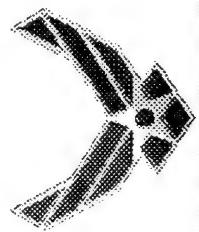
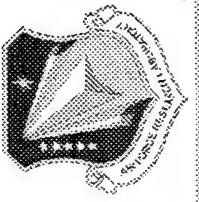
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Flowchart for Experimental Procedure

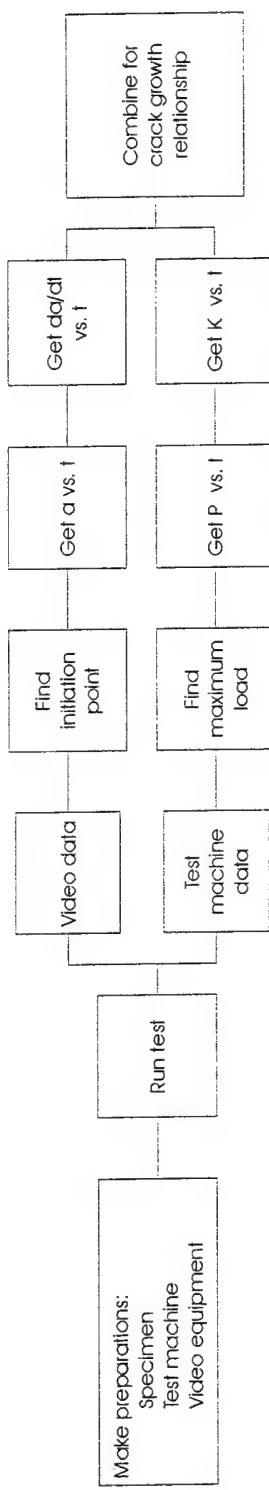


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Nonsmooth or irregular?

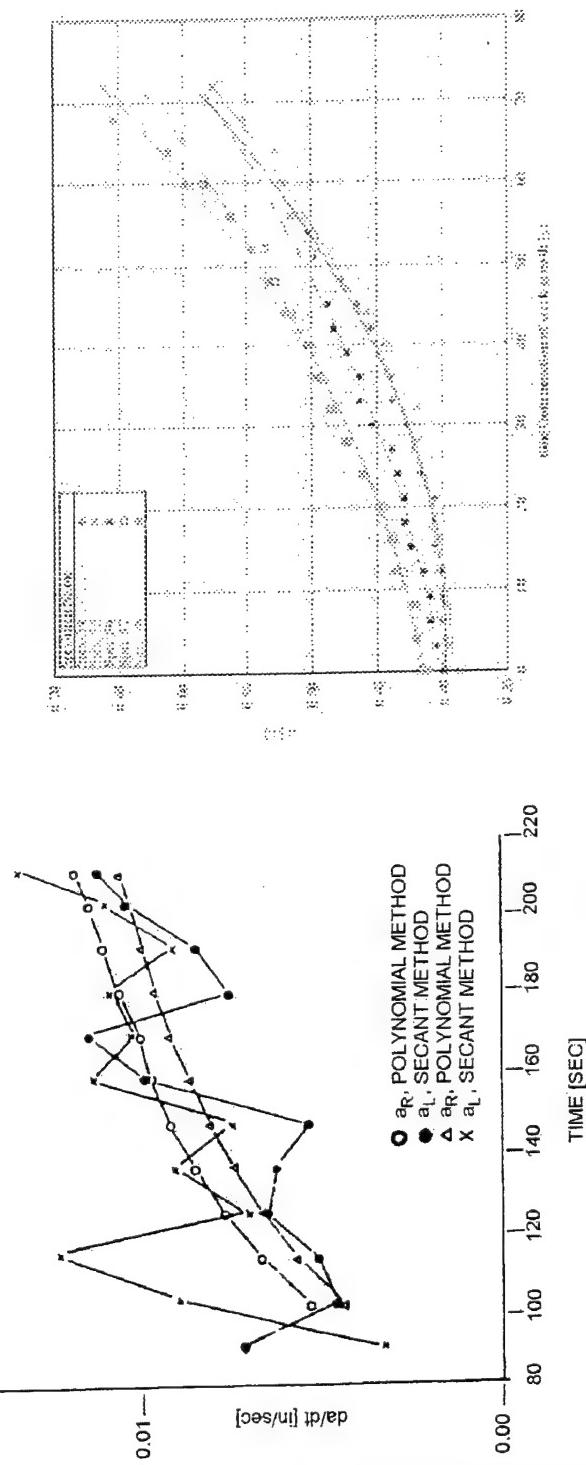
Nonuniform Crack Growth

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Results and Discussion

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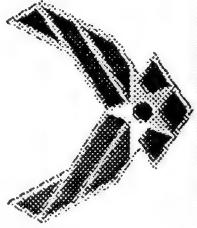
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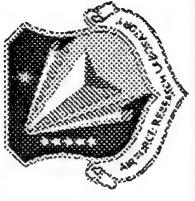
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- Specimen Geometries (SENT, biaxial, surface cracked)

- Pressure Effects



Comparison of Biaxial and SENT Specimen Growth Data



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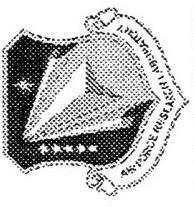
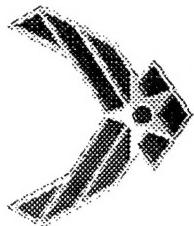
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$$\frac{da}{dt} = C_1 K_1^{C_2} \text{ or } \log\left(\frac{da}{dt}\right) = \log(C_1) + C_2 \log(K_1)$$

Specimen type	$\log(C_1)$	C_2	$\frac{da}{dt}$ (in/sec)
SENT	-6.030	2.084	$90 \text{ psi in}^{1/2}$
Biaxial	-6.590	2.375	0.00100 0.00032

SENT and Surface Cracked Specimen Comparisons



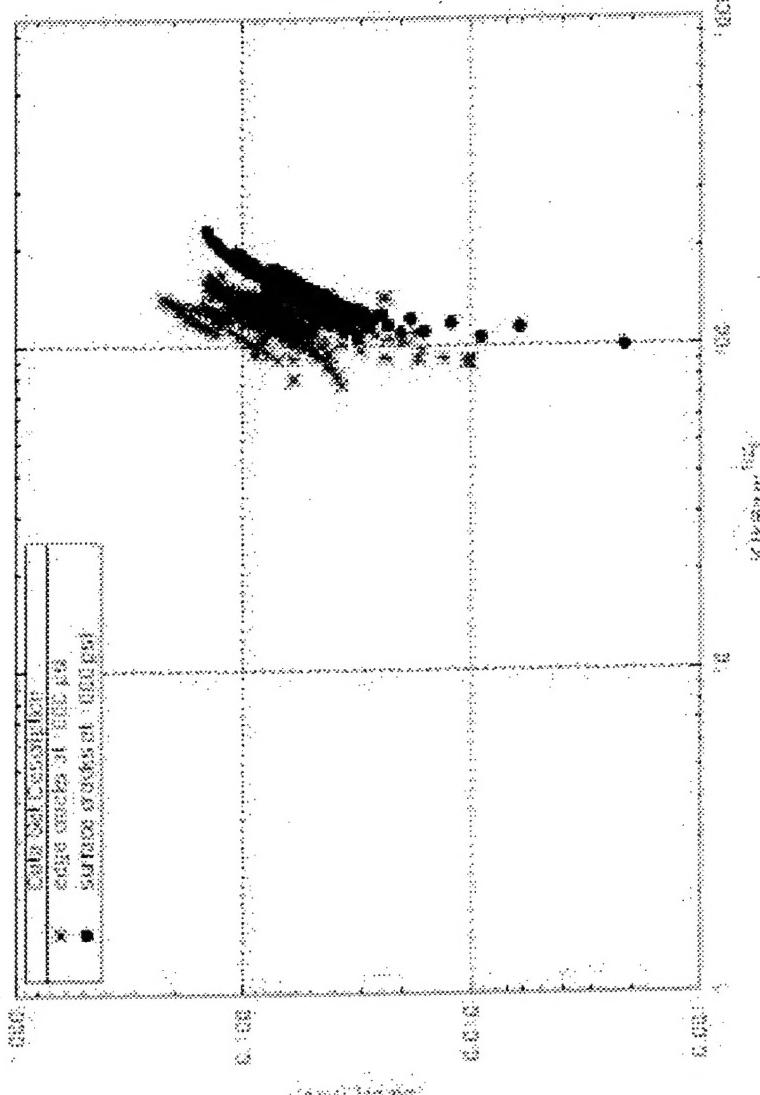
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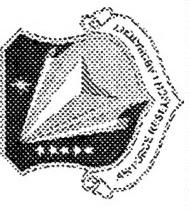
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- Similar growth rates found for both geometries
- Implication: SENT data can be used instead of testing with surface cracked specimens



Ambient Vs. Pressurized Conditions



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- Pressure causes crack growth to slow

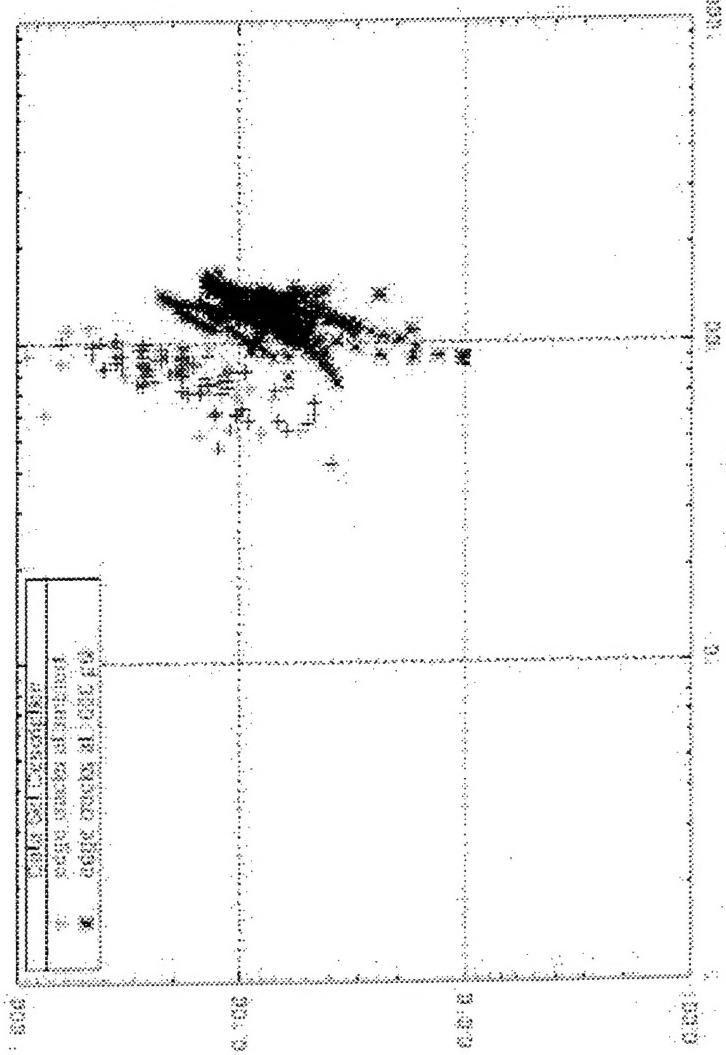
Experimental Procedure

- Microstructural explanation

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- Implication: ambient data may be overly conservative for

Summary and Conclusions



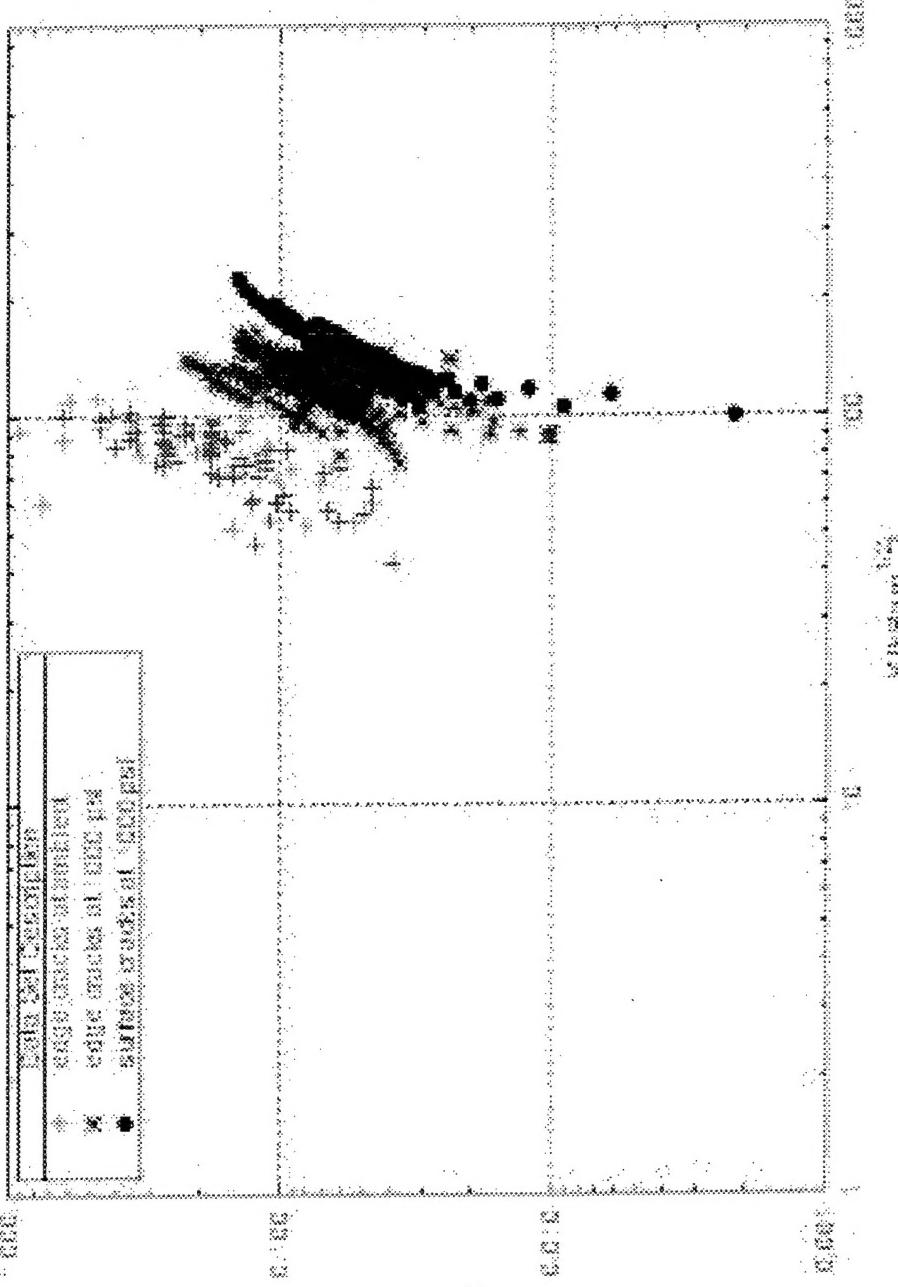
Combination of Data

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Summary and Conclusions



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- Summary: this work has investigated the effect of pressure on fracture behavior of a rubbery particulate composite, and has compared the results for different crack geometries and different pressure conditions.
Pressure delays the onset of crack growth and slows the subsequent growth rate. The results for the specimen geometries tested (both at ambient and 1000 psi (6895 kPa) pressure) show good agreement.
- Conclusions:
 - Good agreement between biaxial, SENT, and surface cracked specimens
 - Pressure inhibits the start of crack growth and slows the subsequent crack growth
 - Pressurized test data should be used to test for pressurized service conditions